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A NEW AUTOMATIC UNLOADER FOR FLAT-BOTTOM BINS [1/]

By H. B. Puckett, Agricultural Engineer [2/]
Agricultural Engineering Research Division

The search for a new-type unloader for flat-bottom bins was initiated because of a need for a dependable supply of feed material for an automatic feeding system. Hopper-bottom bins have been used to a large extent to store feed materials and supply them to the system. It is desirable to use gravity in an automatic system where possible. Hopper-bottom bins utilize gravity for unloading, but usually represent a higher cost per pushel of storage than do other types of bins. This is acknowledged and is accepted because material is available at a single point for convenient withdrawal.

A problem with gravity-powered systems, such as the hopper-bottom bins, is that, although bridging can be minimized and made improbable, it cannot be entirely eliminated. The probability of bridging in a material supply bin must be considered in the design of an automatic feeding system. It is apparent that the hopper-bottom bin is not the last word in feed storage. It also seems quite probable that flat-bottom storage will be with us for a long time. Many farmers who would be interested in installing automatic feed-handling systems are hesitant to discard flat-bottom storage and construct hopper-bottom storage in its place. Two reasons for this are: First, the hopper-bottom storage costs more; and second--I think a less important reason--they are losing storage space.

If an unloader could be provided for flat-bottom storage as it is presently used, and at a cost not exceeding the difference between the flat-bottom storage and an equivalent hopper-bottom storage, it would work well into an automatic feed-handling system.

1/ The work reported in this paper is a result of cooperative research between the Farm Electrification Research Laboratory of the Agricultural Engineering Research Division, ARS, USDA, the Agricultural Engineering Department of the Illinois Agricultural Experiment Station, and the Illinois Farm Electrification Council. Presented at the Winter Meeting of the American Society of Agricultural Engineers, Chicago, Illinois, December 16, 1957.

2/ Located at the Agricultural Engineering Department, Illinois Agricultural Experiment Station, Urbana, Illinois.

While there are several mechanical unloaders for flat-bottom storage, they require some manual labor to remove the last several feet of stored material. This may consist of moving the conveyor and scooping material by hand. The mechanical unloader which we have developed will almost completely unload a flat-bottom bin without human attention. If the stored material can be conveyed by an auger, the unloader will remove it from the bin and deposit it in another conveyor or conveyance at the outside of the bin.

The unloader consists of two augers--a sweep auger to gather the material from the sides of the storage and deliver it to a small hopper in the center of the bin, and a discharge auger to remove the material in the center hopper to the outside of the bin for deposit in another conveyor. The sweep auger is the unique addition to an otherwise ordinary auger unloader. It is an open auger pivoted at the center of the hopper, which is located in the exact center of the bin, and operates a fraction of an inch above the bin floor. This clearance will vary depending upon the trueness of the bin floor. Of course, the closer it is to the floor without touching, the cleaner the bin will be after unloading.

The problem was to power the auger and cause it to press into the stored material with just the proper force. As first conceived, the auger was to be driven through miter gears from a stationary motor. The miter gears were to have a 1:1 ratio, and the final set of two were to be free to rotate in the horizontal plane with the auger resting lightly on the floor. The auger was then to be powered into the material by the friction between it and the bin floor. This plan did not work well. When the auger was permitted to be driven forward by the floor, the material was conveyed on the back side of the auger. This left a layer of material several inches deep in the bin. When a guard was placed behind the auger to form a channel for conveying the material, it caused excessive drag and prevented the auger from advancing into the stored material.

A reappraisal of the force acting upon the auger suggested a unique drive. If the auger was suspended just above the floor, the torque in the vertical drive shaft driving the second set of miter gears would cause the auger to press into the stored material. The material would then be conveyed on the leading edge of the auger, and the stored material would form the necessary conveying channel. Thus less material would be left behind the auger after the first sweep. Further tests demonstrated that approximately 75 inch-pounds of torque would be required to properly load the sweep auger with material. To increase the vertical drive-shaft torque, a drag brake was installed on the sweep auger.

The power lost through drag-brake friction was reasonably high (0.21 hp.). The ratio of the second set of miter gears was changed so that the auger would run faster than the vertical drive shaft and the

proportionate increase in torque would work for the unloader. The result was a decrease in loss of power due to friction (0.07 hp.). Various schemes were considered for mechanically advancing the auger, but their complexity suggested that it was best to use a drag brake that would permit the sweep-auger torque to be easily adjusted and to accept the small power loss caused by the drag brake.

The constant-torque drive had other advantages. When working into a caked meal, the auger will undercut the material, resulting in the collapse of a large amount on top of the auger. If the auger were positively driven in the horizontal plane, it would be overloaded for a longer time than with constant-torque drive. With constant-torque drive the auger is able to reverse its rotation in the horizontal plane and is pushed out of the material. This prevents overloading of the sweep-auger motor.

Some means of controlling the operation of the two augers with respect to each other was necessary. Tests made with both augers operating simultaneously demonstrated this emphatically. Figure 1 shows power requirement as function of depth of material. To operate the sweep auger when the discharge end of it is covered with the stored material results in a waste of power. It takes considerably more power to operate the auger under these conditions than in normal operation. A mechanical clutch to engage or disengage the sweep auger from the drive motor was considered. To make such an operation automatic would have been cumbersome and expensive. Using two motors, one to drive each auger, was a more desirable solution. Automatic control of an electric motor is simpler than automatic control of a clutch or gear shift.

The motor current of the discharge auger fluctuated with the amount of material being conveyed by the discharge auger, Figure 2. This fluctuation amounted to approximately 1 ampere. A current-sensitive relay was installed in the discharge-auger-motor circuit that opened the sweep-auger-motor circuit when the discharge-auger motor was under the proper load. If the current dropped, indicating a nearly empty auger, the sweep-auger motor was turned on to convey material into the center hopper. This control was automatic and repeated the on-off operation for as long as was necessary to supply material to the center hopper. Of course, when the bin was nearly empty, the sweep auger was not able to supply sufficient material to fully load the discharge-auger motor. Then the sweep-auger motor ran continuously.

Another advantage of the automatic control was that a bridge occurring in the bin of the stored material would be broken immediately. This situation would probably occur in soybean oil meal and other oil meals. If a bridge should occur with the auger-type unloader having the automatic sweep-auger control, the sweep auger would operate as soon as the center hopper became empty and would break any bridge that occurred in the bin

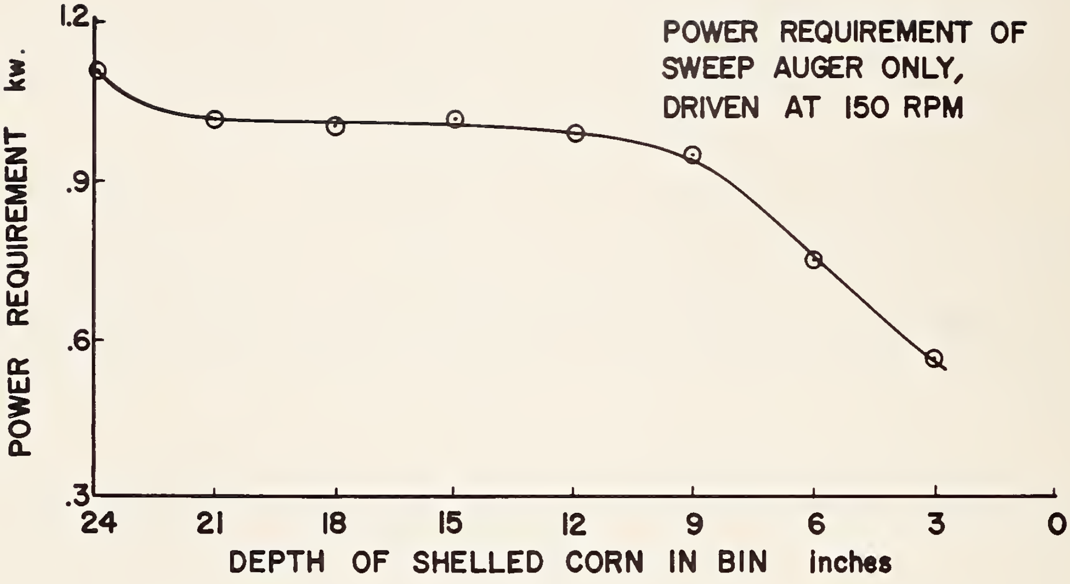

Figure 1. Variation of sweep-auger power requirement with depth of shelled corn in bin.

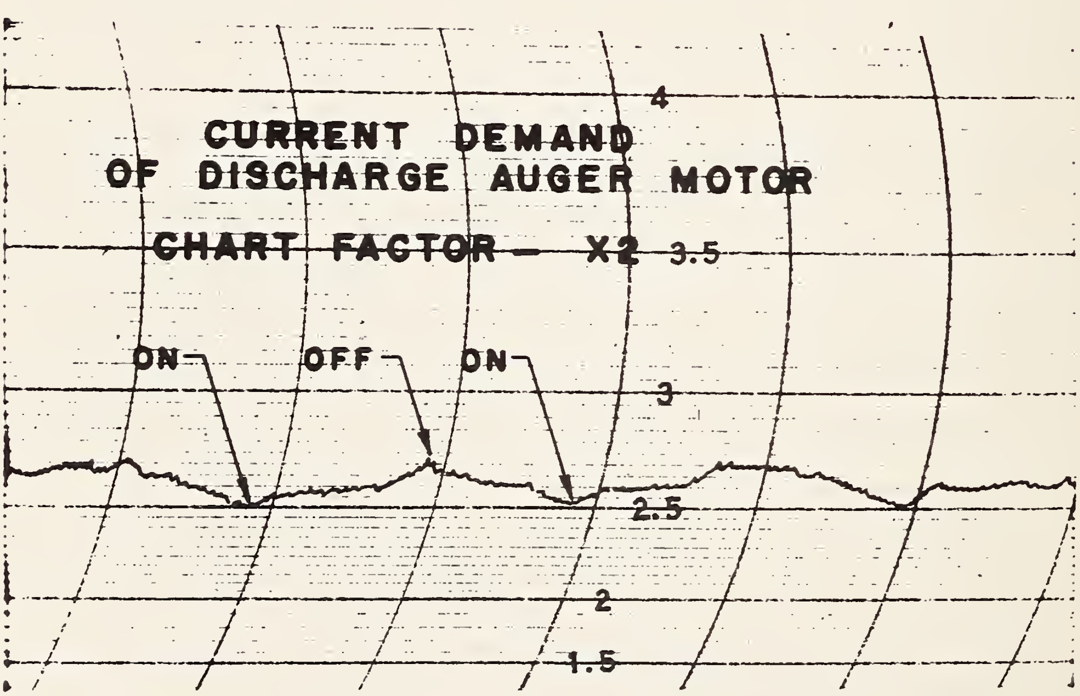

Figure 2. Original sweep-auger motor control design is based on current input to discharge-auger motor.

of stored material. In a round bin the sweep auger would sweep nearly the whole cross section. In a square bin it would sweep about 75 percent of the cross section--that is, sufficiently to insure that any bridge would be broken. Figure 3 shows auger undercutting caked soybean oil meal.

The rate of discharge by the unloader is controlled by auger sizes and the speeds at which they operate, and, of course, the available power. The laboratory unit was designed around 6-inch augers; the sweep auger was driven at 150 r.p.m. and the discharge auger at 100 r.p.m. The unloader withdrew 22,000 pounds of shelled corn per hour, or 18,000 pounds of soybean oil meal per hour. A 1/2-hp. motor was used to drive each auger. The capacity could be easily increased by using larger motors and operating the augers at a higher speed.

An unloader of low capacity will meet the needs of most automatic feeding systems. It is contemplated that this unloader will be installed in an active storage bin--one from which frequent withdrawal of material is necessary. The unloader is designed primarily to handle materials automatically at a low rate. It is used to supply feed materials to an automatic grinder, mixer, or conveyor.

A second unit was constructed for installation in a 14-foot-diameter steel grain bin with 1,000-bushel capacity. This bin was a storage for shelled corn and supplied a 2-hp. automatic grinder. A rate of not more than 1 ton per hour was required from the storage. This unit had a 4-inch sweep auger and a 3.5-inch discharge auger. To further simplify the unit, the sweep-auger motor was located underneath the bin floor beside the discharge hopper. This eliminated the necessity for a rigidly fixed position for the discharge auger. It was now possible to raise or lower the discharge auger or shift it from side to side a few inches for easier installation, Figure 4. A 1/2-hp. motor was used on the sweep auger in the second unit but a 1/6-hp. motor was found adequate to drive the exhaust auger. A sectional view of the unloader is shown in Figure 5.

The current-sensitive relay worked well on the laboratory model, but was more complicated than was desirable. On the second model, a pressure-sensitive switch was installed in the discharge hopper to detect the presence of material in the hopper. This switch in turn directly controlled the sweep-auger motor. When there was no material in the hopper, the switch was in a normally closed position and energized the sweep-auger motor. This conveyed material into the hopper, and the resulting pressure on the switch opened the switch contacts and stopped the sweep-auger motor. This is a simple control and, because of its simplicity, is more reliable and easier to maintain. Its adjustment is not critical, and it does not require adjustment to match the characteristics of the discharge-auger motor, Figure 6.

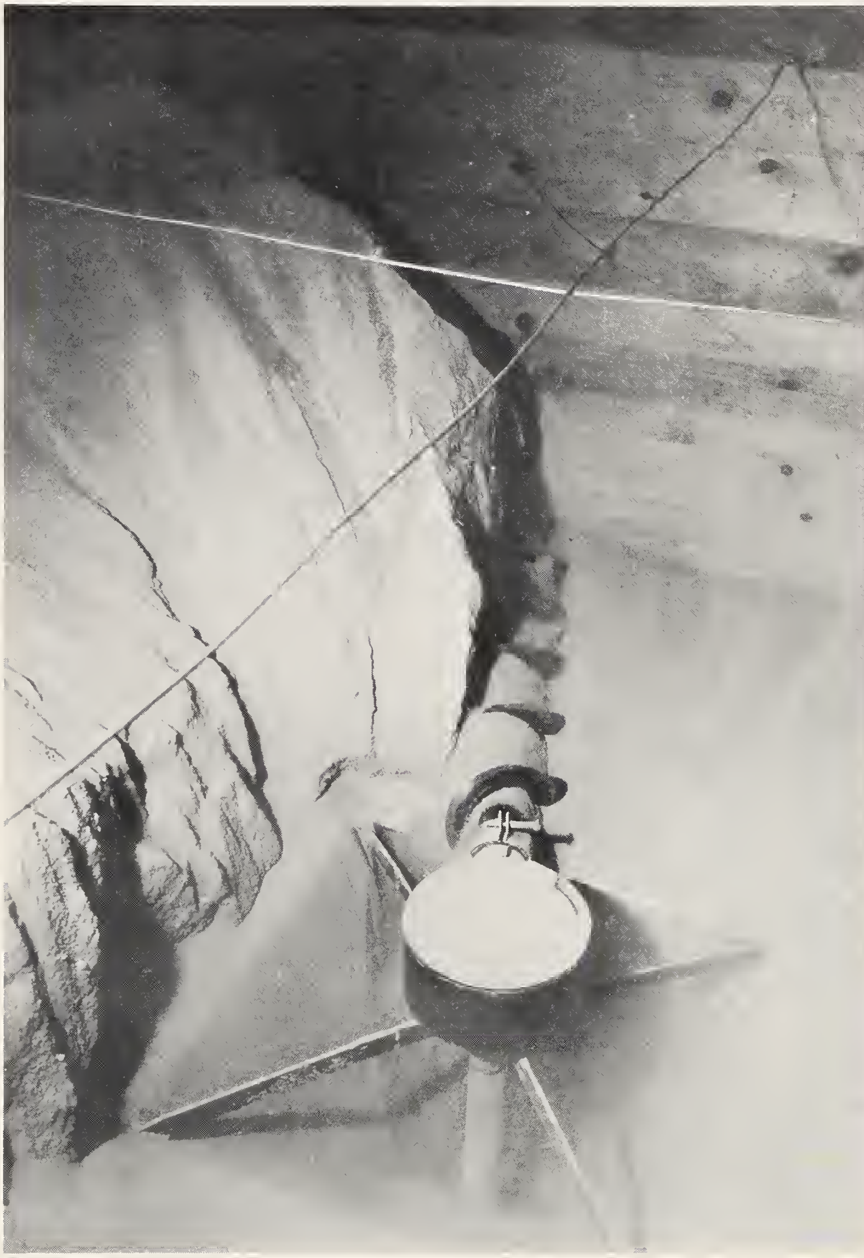

Figure 3. The sweep auger will undercut caked material, causing it to collapse. It is shown removing caked soybean oil meal.

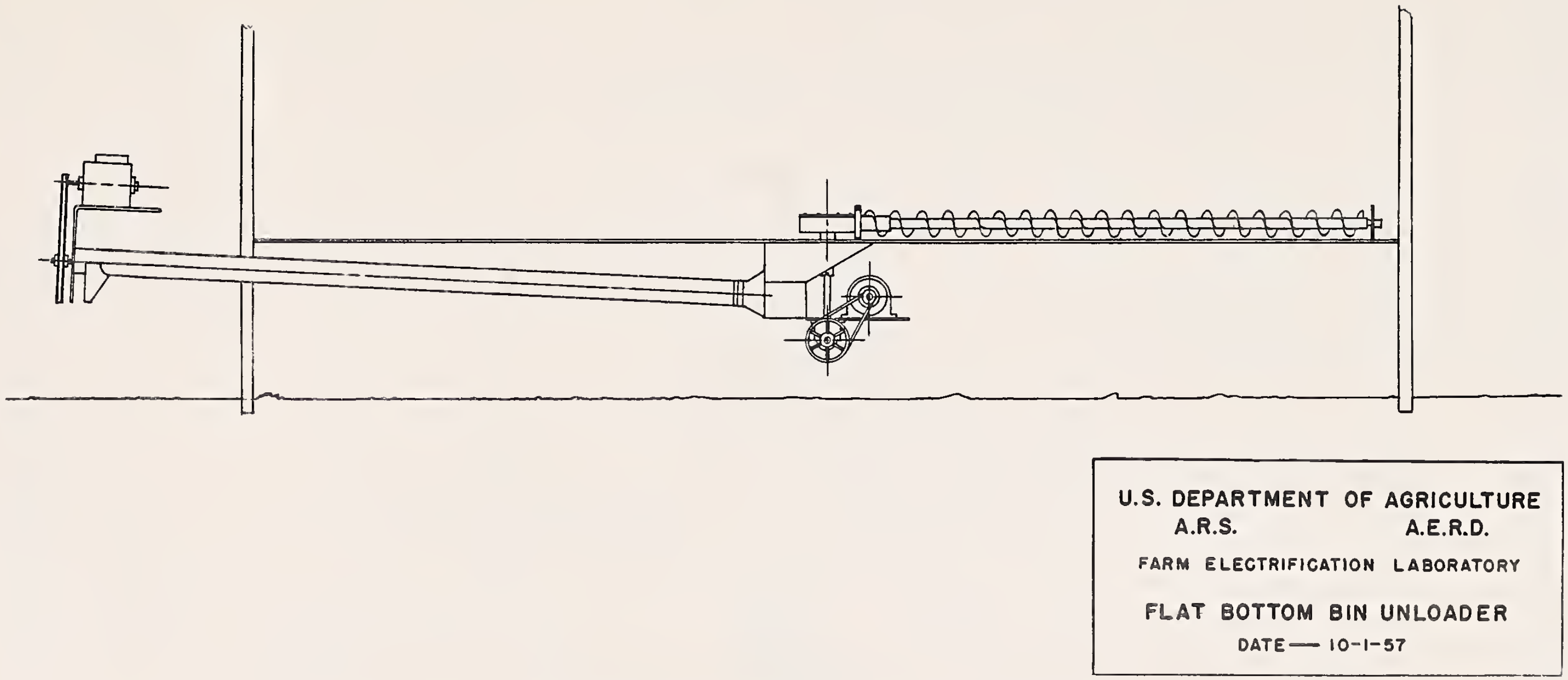

Figure 4. Flat-bottom-bin unloader with sweep auger on right and discharge auger on left.

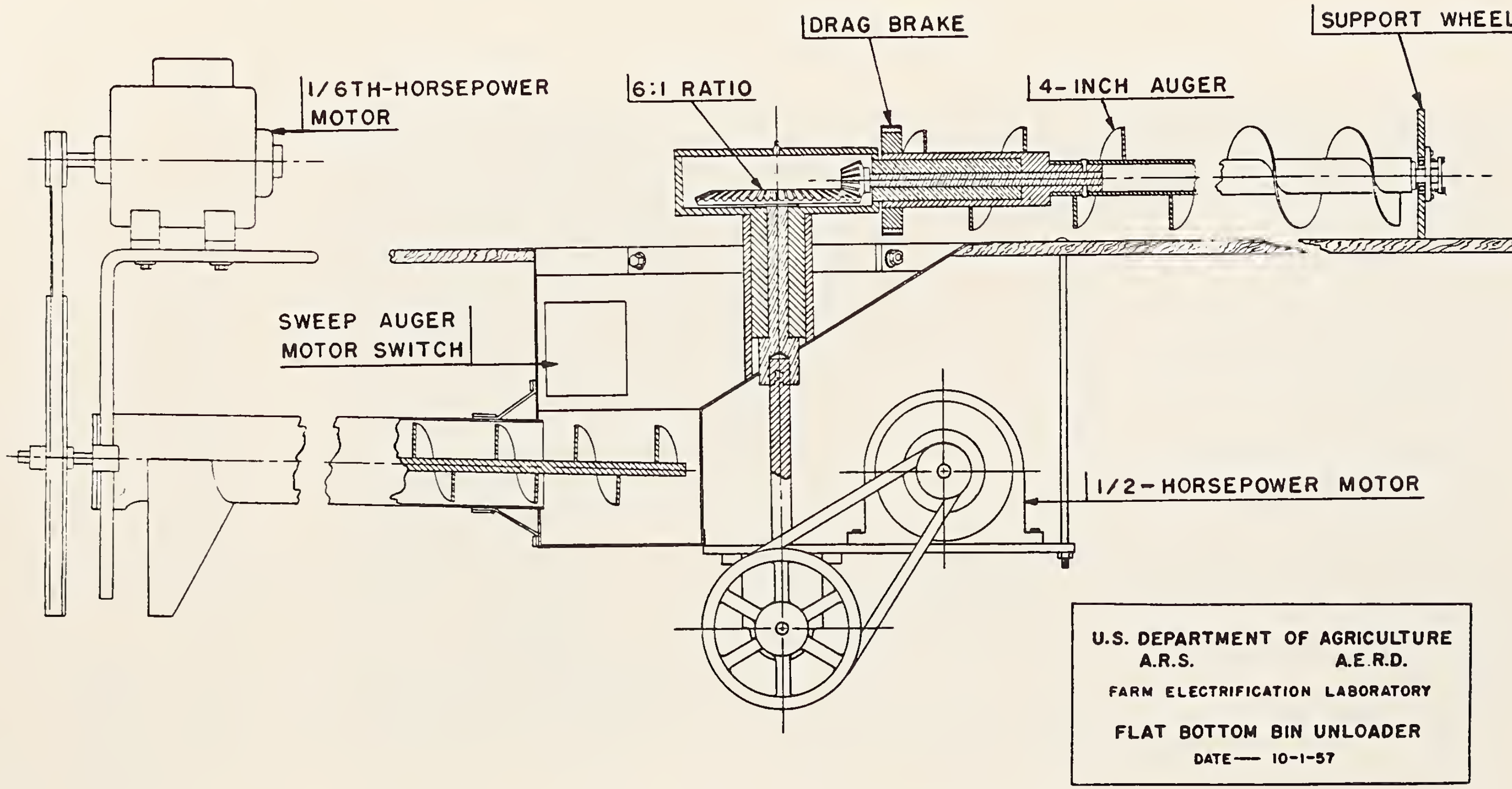

Figure 5. Sectional view of flat-bottom-bin unloader.

SWEEP-AUGER CONTROLLER

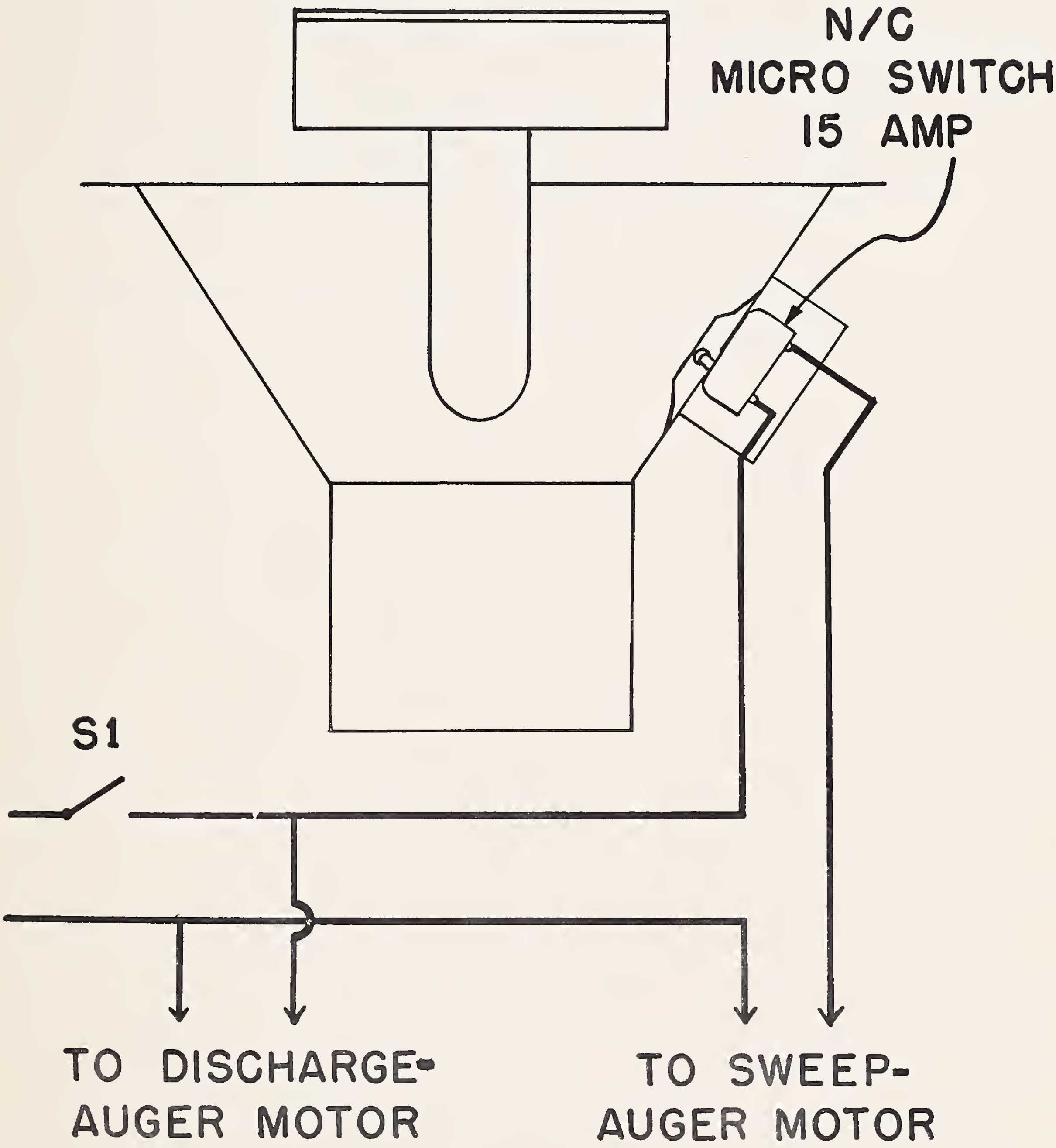

Figure 6. Diagram of sweep-auger motor controller including pressure-sensitive switch.

The 14-foot-diameter bin required an auger with a much longer sweep than had been used in the laboratory tests. This presented two problems: One, how to obtain sufficient torque in the vertical drive shaft to cause the auger to press satisfactorily into the material; and, two, how to support the greater length to prevent it from rubbing against the bin floor. To provide more torque without a resultant increase in power, a higher ratio miter gear was used in the final drive. This ratio was 6:1. A drag brake was also installed, but it was smaller than that installed in the laboratory model. The long auger could not be supported from one end without putting excessive bind on a single bearing. To relieve this bind on the miter-gear bearing, a small wheel was mounted on the end of the auger to run on the floor and support the auger at the proper height. This wheel was not powered. The sweep auger was driven at 180 r.p.m., and the input shaft of the miter gear at 30 r.p.m.

This unit has been very successful and from all indications will meet the need for a simple unloading device for flat-bottom bins used in an automatic materials-handling system.

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